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JOINT PROGRAMME ON THE TECHNICAL DEVELOPMENT AND FURTHER IMPROVEMENT OF IAEA SAFEGUARDS – THE GERMAN MSSP

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ABSTRACT

The "Joint Programme on the Technical Development and Further Improvement of IAEA Safeguards" was established by the Government of the Federal Republic of Germany and the International Atomic Energy Agency (IAEA) in 1978. Since the very beginning, the overall aims of this unlimited project called the "German Member State Support Programme" (GER MSSP) have been to cooperate with the IAEA in developing state-of-art methods and techniques, to assure the supply with the developed methods and techniques, to provide training, expert advice and consultancy on safeguards issues, to delegate cost-free experts to the IAEA, and to inform the IAEA, as early as possible, about Germany's nuclear plans and projects. By 2016, the German MSSP has completed more than 160 tasks, issued more than 420 progress reports and more than 100 technical documents. The German Member State Support Programme currently comprises 20 active tasks. The activities have always been carried out in close cooperation between the Federal Ministry of Economic Affairs and Energy (BMWi), Forschungszentrum Jülich GmbH, IAEA, EURATOM, research institutions and universities, government agencies, nuclear industry, commercial developers, and other IAEA Member State Support Programmes. Most of the safeguards instrumentation developed by the German MSSP has been implemented by the IAEA and EURATOM for routine inspection use. Moreover, facility specific safeguards approaches have been developed for nuclear research centers as well as for the total nuclear fuel cycle including direct final disposal of spent nuclear fuel in a geological repository. The German MSSP has supported the IAEA in the implementation of the Additional Protocol and in the evolution of State-level safeguards. The paper reviews the achievements since 2013 [1], presents the current main areas and activities, and discusses key lessons learned and challenges.

1. INTRODUCTION

The "Joint Programme on the Technical Development and Further Improvement of IAEA Safeguards" was offered to the International Atomic Energy Agency (IAEA) by the Government of the Federal Republic of Germany in September 1978, as the response to the NPT obliging Germany to cooperate with the IAEA in order to facilitate the application of IAEA Safeguards in Germany. Since its official acceptance by the IAEA Director General in October 1978, more than 180 tasks have been performed in close cooperation between the Federal Ministry of Economic Affairs and Energy (BMWi), IAEA, EURATOM, research institutions and universities, government agencies, nuclear industry, commercial developers, and other IAEA Member States Support Programmes.

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The German Member State Support Programme (GER MSSP) emphasizes the joint development of methods and techniques and their commercial provision to the IAEA. In addition, the IAEA is supported by the delegation of cost-free experts to IAEA headquarters. Another essential objective is the as early as possible provision of information about nuclear plans and projects in Germany. Furthermore, the GER MSSP offers the possibility to conduct field tests in commercial facilities, in order to study the performance of newly developed safeguards equipment and procedures under realistic in-field conditions.

Most of the safeguards instrumentation developed by the German Member State Support Programme to the IAEA has been implemented by the IAEA and EURATOM for routine inspection use. Recent instrumentation tasks have focused on the development and implementation of containment and surveillance systems (Next Generation Surveillance System (NGSS), Electronic Optical Sealing System (EOSS)), and measurement methods and techniques for the nondestructive assay of nuclear material (Digital MiniMCA, safeguards-specific user interface for the hand-held gamma spectrometer HM-5).

Moreover, facility specific safeguards approaches have been developed for nuclear research centers as well as for the total nuclear fuel cycle including direct final disposal of spent nuclear fuel in a geological repository. The German Member State Support Programme has supported the IAEA in the implementation of the Additional Protocol and in the evolution of State-level safeguards. By using mathematical models, procedures for estimating optimal inspection strategies as well as for supporting the IAEA's State-level concept (e.g. acquisition path analysis) have been advanced.

Since 2012, the German Member State Support Programme has intensified the research and development activities on the destructive analysis of nuclear materials and environmental samples (qualification for IAEA‘s Network of Analytical Laboratories NWAL, production of reference particles). Other tasks have enhanced geoscientific methods and techniques for safeguards purposes, such as geophysical measurements (seismic, directive radar) for detecting undeclared activities at geological repositories, satellite imagery processing, geo-visualization and simultaneous localization and mapping (SLAM) approaches.

For the implementation of IAEA safeguards in Germany and for safeguards research and development sponsored under the GER MSSP, all responsible federal ministries and federal agencies, state ministries and agencies, nuclear industry as being directly subject to IAEA safeguards, consultancy companies, commercial equipment developers and manufacturers, and research establishments such as research institutes and universities can be addressed and involved. Furthermore, the GER MSSP has cooperated with foreign partners, under joint tasks of several Member State Support Programmes coordinated by the IAEA and through activities under the European Research and Development Association (ESARDA) and the Institute of Nuclear Materials Management (INMM). The US MSSP has always been an important partner of the GER MSSP in conducting joint safeguards development projects for the IAEA; therefore, active contacts between US National Laboratories and German research and development establishments exist.

To the end of enhancing the effectiveness and efficiency of the joint safeguards of IAEA and EU-Commission in Germany, the EURATOM Safeguards Authority is an active partner on a task basis

and a non-voting member of the Joint Committee of IAEA and GER MSSP as well as of the German MSSP Advisory Board, being the two steering bodies of the GER MSSP.

Apart from the safeguards objective, the GER MSSP also has an economic objective, as specialized companies are invited to develop and produce in a high technology market segment.

2. RESULTS OF THE GERMAN SUPPORT PROGRAMME 2013-2016

The GER MSSP is divided into the four areas, to which individual tasks are attributed: A) Safeguards System Designs and Safeguards Approaches; B) Safeguards Data Collection, Treatment and Evaluation; C) Measurement Methods and Techniques; D) Containment and Surveillance. In this chapter a number of noteworthy results since 2013 [1] will be presented. For an overall review of the GER MSSP since 1978, please see [2-4].

2.1 Supporting IAEA‘s State-level Concept (A, B)

The German Member State Support Programme has supported the IAEA in the implementation of safeguards at the State-level [5,6]. Under the joint task “Acquisition Path Analysis (APA) Methodology and Software Package”, some MSSPs were requested to formalize acquisition path analysis methodology and to develop software tools for performing this ongoing analysis in an effective and efficient manner. The GER MSSP has developed a formalized procedure that consists of three steps [7-13]: The first step, network modeling, uses the IAEA's physical model as a basis for parameterizing the model of all relevant processes within a State for converting nuclear source material to weapon usable material. In the second step of the procedure, the network analysis by using mathematical graph theory, all paths with their respective lengths are enumerated, sorted in decreasing order of attractiveness and visualized. In the third step of the procedure, the strategic assessment, the strategic options of both the IAEA and the State are evaluated using a game theoretic approach. Recently, a case study was started on the application of the APA methodology to the Joint Comprehensive Plan of Action (JCPOA), by Iran, the E3+3 and the European Union in July 2015 [14].

Moreover, the GER MSSP has provided studies on the application of statistics and game theory for the optimization of inspection strategies [15,16]. The studies have focused, inter alia, on the efficient calculation of sample sizes for safeguards inspections and verification, so that the desired detection probability will be achieved. Further, methodologies that can quantify efficiency and effectiveness of safeguards measures toward inducing states to legal behavior have been investigated. Research in game theoretic approaches to verification activities in safeguards (compliance verification) has been on-going for decades; however, these approaches do not appear to be widely employed yet. Therefore, the GER MSSP has delegated a Cost-Free Expert to the Section for Nuclear Fuel Cycle Analysis (IFC) within the Safeguards Department's Information Management Division (SGIM) since November 2012, to review and improve existing statistical methodologies and to develop the framework of innovative methodologies needed to support the planning and evaluation of Integrated Safeguards verification activities [17].

2.2 Safeguarding Geological Repositories (A, B)

The GER MSSP is an active member of the Group of Experts on the “Application of Safeguards to Geological Repositories” (ASTOR) [18]. Research and development activities have recently

focused on disposal concepts [19] and geophysical techniques for safeguarding geological repositories. Measurement campaigns at the Gorleben exploratory mine showed the applicability of seismic and acoustic measurement methods to detect clandestine underground mining activities [20,21]. Based on the results, a follow-up project focused on modelling the propagation of seismic waves from different sources in the salt and surrounding sediments [22,23]. Another project investigated the applicability of underground radar technology as a directive and wide ranging technology. Active radar systems could probably be used to set up a protective screen around a geological repository [24,25].

2.3 Safeguards Equipment Development: Non-destructive Assay Instruments (C)

Under the task "Digital Upgrade of Mini Multi-Channel Analyser (MMCA)", the Mini Multi Channel Analyser (MMCA), which is a portable electronics module used for neutron and gamma ray Non-Destructive Assay (NDA) of nuclear material, has been upgraded with state-of-the-art digital technologies, while preserving the main functionality and compatibility with the existing MMCA.

The GER MSSP has recently contracted the Fraunhofer INT to perform a component testing of the MCA-527 (DMCA). Moreover, the GER MSSP has started the upgrade of the MCA-527 to extend the functionality of the device towards neutron counting [26]. Moreover, the functionality of the reporting tool, which generates unified standard reports of safeguards measurements with both the MMCA and the widely used hand-held gamma ray spectrometer HM-5, will be extended to also cover reporting of Electrically Cooled Germanium System (ECGS) measurements.

2.4 Safeguards Equipment Development: Containment and Surveillance (D)

Sealing Systems

While the IAEA uses the Electronic Optical Sealing System (EOSS) for containment and surveillance activities, the task "EOSS Sealing Systems Implementation Support" has provided support for the ongoing modification, upgrade and enhancements of sealing systems at the IAEA as problems are discovered, capability enhancements are identified, or requirements change to meet Safeguards criteria. Recent issues have been solved by firmware updates.

Optical Surveillance Systems

The development of the Next Generation Surveillance System (NGSS) was supported by the GER and the US MSSPs and was completed in December 2011. The task "NGSS Product Lifecycle Support" was established to sustain the implementation of NGSS hardware over the expected technology lifespan for about 15 years. Similar to the EOSS implementation support, the NGSS lifecycle support includes modification, upgrade and enhancements of NGSS surveillance systems. The enhancements, upgrades, or modifications may include the need for hardware modifications, software development, rigorous component and system testing and status discussions.

In a number of safeguards applications, the NGSS core surveillance core component (SCC, DCM-C5) needs to accept input from analog cameras. Therefore, an analog camera input module (ACIM) for the NGSS was developed under task "Analog Camera Support for the NGSS DCM-C5 Surveillance Core Component".

2.5 Facilitating the Implementation of Remote Data Transmission (D)

Following the field demonstration test at the central dry storage facility at Ahaus in 2012/13 [27,28], the implementation of remote data transmission (RDT) in the dry interim storage facilities

in Germany is progressing. Under the task "Testing and Implementation of Data Remote Transmission Security", the GER MSSP has started to support RDT pilot tests in two power reactors. Recently, the IAEA has requested the support of the GER MSSP with regard to the replacement of the current VPN hardware, including private key storage and the cryptographic token.

2.6 Advancing Destructive Analysis (C)

Production and Characterization of Particle Reference Materials

The GER MSSP has supported the IAEA in acquiring standard materials in particulate form that will be used to prepare quality control samples for the network of analytical laboratories (NWAL). Under the task "Production and Characterization of Particle Reference Materials", a particle production setup has been established at Forschungszentrum Jülich [29,30]. Recently, further improvements as to the control of production parameters and the stability of particle production were made. Particles are currently deposited onto flat substrates, and a batch production of approximately 50 substrate samples is possible. In response to the needs expressed by the IAEA, further improvements of the setup are planned allowing for production of particles with smaller sizes and preparation of particles in solution or deposition onto other matrices [31,32].

Qualification of Forschungszentrum Jülich for the IAEA's Network of Analytical Laboratories

The IAEA has requested a change of scope in the qualification of Forschungszentrum Jülich as member of NWAL from the initial plan to provide destructive analysis of nuclear materials. In order to address the urgent need for suitable reference materials for particle analysis of environmental swipe samples, the task title has changed to "Qualification of a Laboratory for Provision of Reference Materials under the IAEA's Network of Analytical Laboratories (NWAL)". The qualification proceeds with determination of technical requirements and the technical evaluation of reference materials for particle analysis.

2.7 Promoting the Application of Satellite Imagery (A, B)

The IAEA requires software and procedures radar imagery processing, hyperspectral imagery analysis, 3D models and Digital Elevation Model production. Under task "Signatures of Nuclear Fuel Cycle Related Processes (Satellite Imagery/Space Borne Remote Sensing Data)", the GER MSSP has provided support on software tools that assist the imagery analysts in their work. The focus has been on 3D models and Digital Elevation Model production from optical and radar satellite data [33], automated change detection using optical and radar satellite data [34-36], as well as on feasibility studies for new sensors, such as the emerging small satellites and the ESA Sentinel missions.

2.8 Enhancing the Application of Geoinformation Technologies (A, B)

In the context of task "Digital Declaration Site Maps", the IAEA has requested support to enable digital submission of Additional Protocol 2a(iii) declarations. If Member States could provide digital state-declared spatial information using standard, compatible formats, the IAEA could directly ingest this information into existing and evolving geoinformation systems. The GER MSSP has developed a framework for the digital delivery of spatial data to the IAEA [37] and has worked on assessing and developing feasible conversion standards from computer-aided design used by the operators to geographic information systems files.

In support of novel technologies under task "MSSP Umbrella Task: Support for Instrumentation Technology Foresight", the GER MSSP has contracted a feasibility study on the use of indoor navigation and mapping using simultaneous localization and mapping (FootSLAM), for safeguards verification purposes. Recently, the GER MSSP provided an evaluation of the PDR (pedestrian dead-reckoning) algorithm and the post-processing algorithm dedicated to the reduction of the usual drift embedded in the inertial navigation system that the IAEA is using. In this context, an algorithm to automatically detect landmarks of the visited area was developed, and a study on using floor plans to correct errors in the odometries was conducted [38].

2.9 Providing Training & Education (B)

The IAEA's Nuclear Trade Unit has been supported by enabling cooperation with a company in the area of vacuum techniques under task "Nuclear Trade Analysis Related Support and Training for Trade and Technology Analysis Unit". In addition, the IAEA makes use of the GER MSSP in terms of occasional workshops, aimed at training its staff in contemporary export control or other relevant issues. Moreover, practical safeguards training courses at enrichment plants have been provided to selected IAEA staff.

2.10 Synergies with (nuclear) security, arms control and disarmament verification

Synergies with (nuclear) security, arms control and disarmament verification are valuable [39]. The tools developed under the GER MSSP for performing APA have proven applicability in a wider context of arms control and disarmament [40-42].

3. SUMMARY & CONCLUSIONS

In the past 38 years, more than 180 tasks have been performed under the GER MSSP in close cooperation with BMWi, IAEA, EURATOM, research institutions and universities, government agencies, nuclear industry, commercial developers, and other IAEA Member States Support Programmes. Most of the safeguards instrumentation developed by the German IAEA Support Programme has been implemented by the IAEA and EURATOM for routine inspection use. Moreover, facility specific safeguards approaches have been developed for nuclear research centers as well as for the total nuclear fuel cycle including direct final disposal of spent nuclear fuel in a geological repository. The GER MSSP has supported the IAEA in the implementation of the safeguards at the State-level.

The activities and experiences of the GER MSSP in the past 38 years have resulted in some **key lessons learned**:

1. Member States Support Programmes have proven to be a powerful vehicle in safeguards implementation, as they a) involve efficiency gains for both IAEA and operators through the development of suitable concepts, methods and techniques, b) allow for close cooperation between operators and the IAEA in field tests and trainings activities on site, and c) facilitate exchange between the IAEA and the respective MS through the delegation of JPOs and CFEs to the IAEA, and provision of expert advice and consultancy.
2. Safeguards research and development in support of implementing safeguards is highly interdisciplinary and benefits from the involvement of experts from very different scientific areas, such as nuclear engineering, nuclear physics, nuclear/radiochemistry, mathematics, geoscience, computer science, political science and law.

3. Close cooperation between MSSP coordinators and contractors (research labs, nuclear industry, commercial developers), IAEA, regional/national safeguards authorities, and operators is essential, in order to efficiently address the requirements and needs of all parties involved.
4. Customized safeguards equipment usually comes in small series production, often from small manufacturers committed to international safeguards. The user requirements for IAEA safeguards equipment regarding reliability and data security are especially challenging and thus call for special designs in many cased. At the same time, commercialization of developed prototypes often implies high production costs and low production rates; therefore, industry may have low interest in performing developments for the IAEA, even though development costs are fully funded by the MSSP.
5. Synergies with (nuclear) security, arms control and disarmament verification can be valuable and should be taken into consideration.

For future development and implementation support under the MSSPs, the GER MSSPs proposes to carefully address **key challenges** as to:

1. Research and development strategy: While MSSPs usually come along with some administrative procedures, it will be important to maintain flexibility and agility in order to support new priorities (resulting from, i.a., SCL implementation) and new activities (e.g. in context of the JCPOA).
2. Instrumentation: In future development tasks, rising economical request for commercial off-the-shelf (COTS) solutions and the user requirements given increased information security risks need to be balanced.
3. Technology foresight: Assuming that a lot of useful technologies exist among the many emerging technologies today that have not yet utilized by the IAEA, the MSSPs should carry on assisting the IAEA in scanning the horizon for novel technologies and ensuring that the Agency is fully aware of technical developments in particular areas.
4. Safeguards culture: Both IAEA and experienced MSSPs should continue to consider using MSSPs as a vehicle for safeguards implementation in States under safeguards, in particular for newcomer States [43]. Experienced MSSPs could act as a kind of mentor for States that intend to establish a MSSP.
5. Human resources: While safeguards research, development and implementation support is a niche market, particular attention should be given to attracting young professionals and retaining safeguards professionals.

4. REFERENCES

[1] I. Niemeyer, M. Dürr, B. Richter, and W. Trautwein, “The German Support Programme to the IAEA: 35 Years of Technical Developments and Further Improvement of IAEA Safeguards,” Proc. INMM 54th Annual Meeting, Palm Desert, 14-18 July 2013

[2] I. Niemeyer, B. Richter, M. Dürr, D. Bosbach, and W. Trautwein, “35 Years of Joint Programme on the Technical Development and Further Improvement of IAEA Safeguards (1978 – 2013),” Report GER MSSP, JOPAG/11.13-PRG-403, 2013

[3] H.H. Remagen, A. Rezniczek, B. Richter, and G. Stein, “Fifty Years of the International Atomic Energy IAEA and German Contributions to the Development of International Safeguards,” Journal of Nuclear Management (JNMM) 35 (4), pp. 32-41, 2007

[4] B. Richter and H.H. Remagen, “The German Research and Development Programme in Support of the International Atomic Energy IAEA, Achievements of 25 Years,” atw/International Journal for Nuclear Power 49 (8/9), pp. 541-549, 1994

[5] F. Sevini, I. Niemeyer, A. Vincze, and K. v.d Meer, “ESARDA Contributions to IAEA State-level Concept,” Proc. INMM 55th Annual Meeting, Atlanta, 21-24 July 2014

[6] G. Stein, A. Rezniczek, I. Niemeyer, C. Listner, and W. Trautwein, “The Evolution of International Safeguards - A View from Germany,” Proc. INMM 55th Annual Meeting, Atlanta, 21-24 July 2014

[7] C. Listner, M.J. Canty, G. Stein, A. Rezniczek, and I. Niemeyer, “Quantifying Detection Probabilities for Proliferation Activities in Undeclared Facilities,” Proc. IAEA Symposium on International Safeguards: Linking Strategy, Implementation and People, Vienna, 20-24 Oct. 2014

[8] C. Listner, Murphy, C.L., M.J. Canty, G. Stein, A. Rezniczek, and I. Niemeyer, “Evolution of Safeguards - What Can Formal Acquisition Path Analysis Contribute?” Proc. INMM 55th Annual Meeting, Atlanta, 21-24 July 2014

[9] C. Listner, M.J. Canty, G. Stein, A. Rezniczek, and I. Niemeyer, “Formalizing Acquisition Path Analysis for the IAEA's State-Level Concept,” Proc. 37th ESARDA Symposium on Safeguards and Nuclear Material Management, Manchester, 18-21 May 2015

[10] C. Listner, I. Niemeyer, M.J. Canty, G. Stein, and A. Rezniczek, “Formalizing Acquisition Path Analysis for the IAEA’s State-Level Concept,” Proc. INMM 56th Annual Meeting, Indian Wells, CA, USA, 12-16 July, 2015

[11] C. Listner, I. Niemeyer, M.J. Canty, C.L. Murphy, G. Stein, and A. Rezniczek, “Acquisition Path Analysis Quantified – Shaping the Success of the IAEA’s State-level Concept,” Journal of Nuclear Materials Management 43(4), pp. 49-59, 2015

[12] M.J. Canty, “A Game Theoretical Evaluation Methodology for the Analysis of Clandestine Acquisition Paths (Revised Status Report),” Report GER MSSP, JOPAG/11.15-PRG-418, 2015

[13] C. Listner, I. Niemeyer, M.J. Canty, and G. Stein, “A Strategic Model for State Compliance Verification,” Naval Research Logistics 63(3), pp. 260-271, 2016

[14] J. Rutkowski, I. Niemeyer. M.J. Canty, A. Rezniczek, and G. Stein, “Acquisition Path Analysis Modeling Using the Joint Comprehensive Plan of Action as a Case Study,” Proc. INMM 57th Annual Meeting, Atlanta, 24-28 July 2016

[15] R. Avenhaus and T. Krieger, “Inspections over Time: The Role of Information,” Proc. IAEA Symposium on International Safeguards: Linking Strategy, Implementation and People, Vienna, 20-24 Oct. 2014

[16] R. Avenhaus and T. Krieger, “Inspection Games over Time: Fundamental Models and Approaches. Monograph on inspection games,” in preparation

[17] T. Krieger, “Statistical Methods for Verification Sampling Plans,” Safeguards Technical Report (STR), International Atomic Energy Agency, Vienna, 2016

[18] I. Niemeyer, Altmann, J., Filbert, W., Kaiser, S., Uchtmann, S., and W. Trautwein, " Safeguarding Geological Repositories – R&D Contributions from the German Support Programme," Proc. IAEA Symposium on International Safeguards: Linking Strategy, Implementation and People, Vienna, 20-24 Oct. 2014

[19] W. Filbert, "German Disposal Concepts for High-Level Waste and Spent Fuel in Rock Salt Formations," Report GER MSSP, JOPAG/12.13-PRG-405, 2013

[20] J. Altmann and H. Kühnicke, "Acoustic and Seismic Measurements for the Detection of Undeclared Activities at Geological Repositories. Results from the Gorleben Exploratory Mine," Report GER MSSP, JOPAG/11.13-PRG-404, 2013

[21] J. Altman., "Seismic Monitoring of an Underground Repository in Salt – Results of the Measurements at the Gorleben Exploratory Mine", ESARDA Bulletin 50, pp. 61-78, 2013

[22] J. Altmann, "Modelling of Seismic-Wave Propagation at a Salt Dome. Final Report," Report GER MSSP, JOPAG/12.15-PRG-422, 2015

[23] J. Altmann, "Modelling Seismic-Signal Propagation at a Salt Dome for Safeguards Monitoring," ESARDA Bulletin 52, pp. 60-79, 2015

[24] S. Uchtmann, C. Holst, and D. Orlowsky, "Radar Monitoring - Detectability of Undeclared Activities," Proc. IAEA Symposium on International Safeguards: Linking Strategy, Implementation and People, Vienna, 20-24 Oct. 2014

[25] S. Uchtmann, K. Siever, and C. Holst, "Evaluation of the Applicability of the Directional Radar Technology for Safeguarding Geological Repositories," Report GER MSSP, JOPAG/09.15-PRG-416, 2015

[26] R. Berndt, J. Brutscher, and P. Mortreau, "Neutron Counting and Gamma Spectrometry with MCA-527," Proc. IAEA Symposium on International Safeguards: Linking Strategy, Implementation and People, Vienna, 20-24 Oct. 2014

[27] A. Jussofie, K. van Bevern, M. Hahn, and W. Trautwein, "Germany's Accelerated Exit from Nuclear Energy: Challenges and Perspectives with regard to Safeguards," Proc. IAEA Symposium on International Safeguards: Linking Strategy, Implementation and People, Vienna, 20-24 Oct. 2014

[28] A. Jussofie, K. van Bevern, W. Geißler, I. Niemeyer, A. Rezniczek, W. Trautwein, and K. Schoop, "An update on the implementation of remote data transmission (RDT) in the dry interim storage facilities in Germany," Proc. 37th ESARDA Symposium on Safeguards and Nuclear Material Management, Manchester, 18-21 May 2015

[29] A. Knott and M. Dürr, "Production of monodisperse uranium particles for nuclear safeguards applications," ESARDA Bulletin 49, 2013, pp. 40-45

[30] A. Knott, M. Dürr, I. Niemeyer, and D. Bosbach, "Towards Production of Monodisperse Reference Particles for Nuclear Safeguards Applications," Proc. INMM 55th Annual Meeting, Atlanta, 21-24 July 2014

[31] M. Dürr, A. Knott, R. Middendorp, I. Niemeyer, S. Küppers, M. Zoriy, M. Froning, and D. Bosbach, "Activities at Forschungszentrum Jülich in Safeguards Analytical Techniques and

Measurements," Proc. IAEA Symposium on International Safeguards: Linking Strategy, Implementation and People, Vienna, 20-24 Oct. 2014

[32] M. Dürr, R. Middendorp, A. Knott, "Preparation of Uranium Micro-Particles as Reference Material for Nuclear Safeguards," Proc. 37th ESARDA Symposium on Safeguards and Nuclear Material Management, Manchester, 18-21 May 2015

[33] P. d'Angelo, C. Rossi, C. Minet, M. Eineder, M. Flory, and I. Niemeyer, "High Resolution 3D Earth Observation Data Analysis for Safeguards Activities," Proc. IAEA Symposium on International Safeguards: Linking Strategy, Implementation and People, Vienna, 20-24 Oct. 2014

[34] I. Niemeyer, "Spaceborne Verification: Satellite Imagery Within Nuclear Nonproliferation and Arms Control Verification Regimes," Proc. 56th Annual INMM Meeting, Indian Wells, CA, USA, 12-16 July, 2015

[35] I. Niemeyer, C. Listner, M.J. Canty, Wolfart, E., and J.-M. Lagrange, "Integrated Analysis of Satellite Imagery for Nuclear Monitoring - Results from G-SEXTANT," Proc. INMM 55th Annual Meeting, Atlanta, 21-24 July 2014

[36] I. Niemeyer, M.J. Canty, J.-M.Lagrange, C. Listner, D. Schwartz, S. Uruñuela Hernández, and E. Wolfart, "Integrated Analysis of Satellite Imagery for Nuclear Monitoring - G-SEXTANT Findings," Proc. 37th ESARDA Symposium on Safeguards and Nuclear Material Management, Manchester, 18-21 May 2015

[37] S. Nussbaum, "Development of a framework for the digital delivery of spatial data for the International Atomic Energy Agency (IAEA) as part of the declaration activities of the Member States", Report GER MSSP, JOPAG/03.15-PRG-406, 2015

[38] S. Kaiser, E. Munoz Diaz, "FootSLAM2: Enhancing IAEA's Navigation Algorithm for use in Complementary Access Inspections," Report GER MSSP, JOPAG/04.16 PRG-423, 2016

[39] M. Göttsche, M. Kütt, G. Neuneck, I. Niemeyer, "Advancing Disarmament Verification Tools: A Task for Europe?" EU Non-Proliferation Consortium Non-Proliferation Papers No. 47, 2015

[40] M. Dreicer, C. Listner, C. Chen, G. Stein, and I. Niemeyer, "Applying State-level Approaches to Arms Control Verification," Proc. INMM 55th Annual Meeting, Atlanta, 21-24 July 2014

[41] K. Allen, M. Dreicer, C. Chen, I. Niemeyer, C. Listner, and G. Stein, "Systems Approach to Arms Control Verification," ESARDA Bulletin 53, pp. 83-91, 2015

[42] C. Chen, M. Dreicer, K. Allen, I. Niemeyer, C. Listner, and G. Stein, "Developing a Systems Concept to Arms Control Verification — Results from the ESARDA VTM WG Workshop," Proc. INMM 56th Annual Meeting, Indian Wells, CA, USA, 12-16 July, 2015

[43] E. Martikka, T. Honkamaa, M. Hämäläinen, T. Lamminpää, and P. Tuulensuu, "Newcomer States and Finnish Safeguards Support Programme to the IAEA," Proc. INMM 57th Annual Meeting, Atlanta, 24-28 July 2016